PATENT SPECIFICATION

759,700

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EXAMINER'S COPY DIV.

COMPLETE SPECIFICATION

Improvements in and relating to Electric Feeler Control Systems for Machine Tools

We, SOCIETE AUTOMATA, a French Body Corporate, of 111, quai de Javel, Paris 15, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to copying machine tools in which relative movement between the tool and the workpiece is governed by electrical signals or orders produced as a result of the deflection of a feeler out of a normal position during exploration of a pattern by the feeler.

According to the invention, the machine has a table arranged for rectilinear displacement in opposite directions by electrical driving means controlled by the said orders and carries at least one workpiece support arranged for movement relatively to the table by electrical driving means controlled by the said orders. A set of contacts is also provided which are actuated successively by the feeler as its deflection increases and which control relays arranged in the circuits of the driving means for the table and the support so that the support can be moved in at least five different manners.

In one arrangement in accordance with the invention, the workpiece support is in the form of a turntable mounted for rotation in both senses. In another, the support is mounted for rectilinear movement in opposite directions transversely to the movement of the table. In both these cases, seven different kinds of movement of the workpiece can be produced.

If the workpiece is carried by a turntable which is itself carried by a rectilinearly movable support, a still greater number of different kinds of movement can be produced.

The various movements of the table and workpiece carrying support or supports can be made at constant speed. However, by incorporating a speed regulator in one or more of the control circuits, the speed of any particular movement can be varied. The speed regulator can usefully be of the kind which allows current to pass through it intermittently, the amount of current passing at each pulse being adjustable by the operator in accordance with the speed which is desirable at any particular time.

The speed control does not involve any alteration in the number of control contacts or relays. A machine designed for constant speed operation can be converted to variable speed operation by the simple addition of a speed regulator.

The machine enables a pattern to be explored in different manners by causing the various signals or orders to be emitted in different sequences. A selector can be provided to enable the operator to set the machine for that one of a number of manners of exploration which is best suited to the workpiece to be machined.

The accompanying drawings show a number of arrangements in accordance with the invention.

Fig. 1 of the drawings is a perspective view of a vertical milling machine having a pattern turntable and two workpiece turntables:

Figs. 2-5 are diagrams showing four different positions of the feeler during exploration of the pattern:

Fig. 6 shows the manner in which the pattern is explored:

Fig. 7 illustrates the machining of complementary male and female parts by the exploration of a single pattern:

Fig. 7A shows the cycle of movements in the case of the machine shown in Fig. 7:

Fig. 8 shows the manner in which a complex pattern can be explored: and

Fig. 8A the cycle of exploratory movements:

Fig. 9 shows the exploration of a pattern by a reeler in a machine providing for seven

[Price 3/-]

different kinds of movement, the movements being shown in Fig. 9A:

Fig. 10 shows how seven different signals or orders can be generated by movement of a feeler:

Fig. 10A shows the seven movements controlled by those orders and Fig. 10B is a table showing the condition of various relays shown in Fig. 10 on the emission of the various orders and the movements which result therefrom:

Fig. 11 shows an application of the invention to three-dimensional machining:

Fig. 12 shows a selector by means of which any one of various manners of exploration (Figs. 13, 13A to Figs. 18, 18A) can be selected at will:

Fig. 19 is a view corresponding to Fig. 10 showing a machine providing for seven different kinds of movement and for speed regulation: and

Fig. 19A is a diagram showing the condition of the control relays for each of the seven different kinds of movement.

Fig. 1 shows a milling machine set up to produce complementary female and male articles (such as a punch and a die) from a single male pattern 5. The machine has a main table or carriage 1 on which are mounted three rotary tables 2, 3 and 4. The pattern 5 is mounted on the rotary table 2 and is explored by a feeler 6. Two workpieces 7 and 8 are mounted on the rotary tables 3 and 4. All three rotary tables 2, 3 and 4 are actuated through a reversible magnetic clutch 9 and the longitudinal carriage 1 is actuated in the direction A-B by a reversible magnetic clutch 10. The feeler is mounted an a cross slide 11. The two cutters are driven by motors 12 and 13 and the cutter 14 is adjustable relatively to the cutter 15 in the direction A-B by means of a hand wheel 16 which can usefully be provided with a vernier to allow precise adjustment to be effected in accordance with the diameter of the cutter. At the instant at which the machine is put into action, the feeler controls the two reversible magnetic clutches 9 and 10 and automatically explores the external contour of the template 5. The cutter 14 cuts the internal contour of the die 7 while the cutter 15 cuts the external contour of the punch 8.

The feeler is of the kind having a spindle which is deflected out of a normal position when a finger on its end is caused to make contact with the pattern and which, by its deflection, causes electrical signals or orders to be transmitted for controlling the movement of the pattern and workpieces.

Figs. 2, 3, 4 and 5 show the finger 18 of the feeler in four typical positions relatively to the pattern. Fig. 2 shows the finger 18 at a certain distance from the pattern 5. The feeler spindle not being deflected, the machine is controlled by signal or order I which determines that the magnetic clutch 9 is disengaged so that the table 2 is at rest on the carriage 1 while the clutch 10 is engaged to move the carriage in the direction A.

Fig. 3 illustrates the instant at which the finger 18 touches the pattern. The spindle of the feeler is then deflected and the machine is under the influence of order II which determines that the clutch 10 is disengaged so that the longitudinal movement of the carriage is interrupted while the clutch 9 is engaged so that the table 2 is turned.

As long as the deflection of the feeler remains unchanged, order II will persist, the table being turned through an angle α as shown in Fig. 4. If the magnitude of the deflection increases, order III is initiated so that the clutch 9 opens and the rotary movement stops while the clutch 10 then closes and the carriage moves in the direction B carrying the pattern away from the feeler.

If, however, the magnitude of the deflection of the feeler decreases, order I is again initiated, the rotation of the pattern being stopped and the carriage being moved in the direction A as in Fig. 1.

Thus, the pattern is explored in a series of steps as indicated in Fig. 5.

Fig. 6 is a diagram showing to a larger scale the path of exploration of a pattern in a machine in which provision is made for the orders I, II and III explained above. In practice, the steps would be of smaller dimensions relatively to those of the pattern than those shown which have been amplified in the interests of clarity. From the point a to the point b, alternation occurs between the orders I and II and from the point b to the point c alternation occurs between the orders II and III.

If male and female objects are to be produced by the exploration of one and the same pattern, the tools acting on the two workpieces have to be differently set.

The locus of the axis of the feeler when following an external contour is shown at 19 on the right hand side of Fig. 7. The path 19 is displaced outwards from the contour of the pattern by half the diameter of the finger 18 of the feeler. Assuming the cutter 15 to be of the same diameter as the finger 18, if the axis of the cutter is disposed at a distance d from the axis of the feeler so that the locus of the cutter axis is as shown at 20, the part 21 will be machined to the same size as the pattern. If, however, it is desired to mill an internal contour, the cutter, as indicated by the reference 14, must be laterally adjusted so that the distance between the locus of the cutter axis and that of the feeler axis is d-e, e being the diameter of the cutter. In the case of a machine with two cutters as shown in Fig. 1, by adjustment of the cutters, a punch and a

die can thus be milled simultaneously from a single pattern.

The diagram shown in Fig. 7A indicates the seven movements of the feeler which are necessary for exploring the pattern.

Fig. 8 shows the exploration of a more complex pattern in a machine in which provision is made for five orders I, II, III, IV, V. This figure shows the steps resulting from the exploration and those portions of the pattern which can not be sensed by the feeler. The five orders which are provided in this case are the three already described in connection with Fig. 6 and two further orders determining rotation of the tables simultaneously with longitudinal displacement of the carriage. That exploration system adapts itself much better to the contour because during orders II, III and IV, the movement of the rotary tables will not be interrupted. This method of exploration while particularly suitable for a large number of shapes, is not suitable for every kind of shape.

As in the case under consideration only five different orders are provided for, the feeler cannot be caused to follow sufficiently accurately certain parts of a complicated pattern such as that shown in Fig. 8. Thus, no provision is made for an order producing movement in the direction required to enable the feeler to follow the cross-hatched part F1 which lies above the line *f h* or the cross-hatched part F2 which lies above the line *f g*.

With a feeler providing for seven orders I-VII which are successively initiated with continuous increase in the magnitude of deflection of the feeler in the sequence shown in Fig. 9A, the feeler can be made to follow patterns having the shape shown in Fig. 9 and patterns of even more difficult shape.

The Roman numerals in Fig. 9 show the exploratory movements made in response to the various orders.

Order I results in clockwise rotation of the table with movement of the carriage to the right (relative movement of feeler to the left): order II results in movement of the carriage to the right without rotation of the table: order III, in movement of the carriage to the right with counterclockwise rotation of the table: order IV, in counterclockwise rotation of the table without movement of the carriage: order V, in movement of the carriage to the left with counterclockwise rotation of the table: order VI, in movement of the carriage to the left without rotation of the table: order VII, in movement of the carriage to the left with clockwise rotation of the table.

Fig. 10 shows diagrammatically how the seven orders I-VII can be initiated. The carriage 1 can be actuated in the direction A-B by a screw 23. According as the magnetic clutch 10 is connected across the terminals 41, 42 or 42, 43, the screw 23 is rotated clockwise or counterclockwise by a motor 47 through a shaft 48, the two bevel wheels 45, 46 and a shaft 44. The tables 3 and 4 are driven by the motor 47 clockwise or counterclockwise through the shaft 48, the electro-magnetic clutch 9, bevel gearing 52, 53 and worm gearing 50, 51 according as the clutch is connected across one or the other of the two pairs of terminals 41*a*, 42*a* or 42*a*, 43*a*. The pattern 5 is mounted on the rotary table 3 and the workpiece 8 on the table 4. The finger 18 of the feeler follows the contour of the pattern and the workpiece is milled accordingly by the cutter 15. When the finger 18 of the feeler is not in contact with the pattern, the spindle 54 of the feeler will be in the vertical or normal position. The spindle is pivotally mounted at 55 so that it can be deflected in all directions and, by displacement of its pointed upper end 56 in a conical recess in a block 57, cause the latter to be displaced upwards. The block 57 has an upward extension 58 from which project laterally lugs which can be caused to act on the centre blade 30, 32, 38 or 40 of four three-blade contacts connected to relays R1, R2, R3, R4 serving to control the clutches 10 and 9 in accordance with the deflections of the feeler. Fig. 10A shows the movements corresponding to the seven orders I-VII initiated as the spindle of the feeler is deflected by increasing amounts out of its normal position. Fig. 10B indicates the condition of the relays corresponding to different orders of the feeler and the corresponding movements which are effected in consequence.

Fig. 10 does not show the contacts in any particular working position. Initially, the feeler being in its vertical, undeflected position, the centre blade 38 is out of contact with its companion blades while the centre blades 30, 32 and 40 are in contact with their lower companion blades 29, 31 and 39 respectively. It is in that setting of the contacts that order I is initiated. Increasing deflection of the feeler causes the block 57 to rise and the centre blades to be urged upwards by the lugs in the order 32, 30, 40 causing the various order to be initiated in sequence.

When, the feeler being out of contact with the template and, therefore, vertical, order I is initiated, as indicated in Fig. 10B, the relays R1 and R4 are de-energised and the relays R2 and R3 energised. The two rotary tables turn in the direction R while the cutter carriage moves towards B. As soon as the pattern touches the feeler, the latter is deflected and order II is initiated so that the relay R4 is energised. The relays R2, R3, R4 being energised, the clutch 9 is disengaged and the only movement will be that of the cutter carriage in the direction B. On

further deflection of the feeler order III is initiated with consequent de-energisation of the relay R3 and rotation of the rotary tables in the direction L. As indicated in Fig. 10B seven different kinds of movement are determined by the relays R1, R2, R3, R4. The relays have rest contacts and the clutches are engaged only if the relays are currentless. If, therefore, a relay winding is defective, the fault will immediately become apparent.

For order I, the relay R2 will be energised through the contacts 29, 30 which, as already explained are in contact with each other when the feeler is vertical: the relay R3 is also energised through the contacts 31, 32 which are also in contact with each other. The clutch 10 will receive current through the rest contacts 33 and 34 of the non-energised relay R1 and the terminals 41, 42. The clutch 9 will receive current through the rest contacts 35, 36 of the relay R4, which is likewise not energised, and the terminals 41*a*, 42*a*.

For order II, the pair of contacts 37, 38 will be closed by the ascent of the block 57, the pair 39, 40 remaining closed. The relay R4 will then receive current through the contacts 39, 40 so that the rotary movement of the table will be stopped.

For order III, the pair of contacts 31, 32 are opened so that the relay R3 drops and rotary movement of the table in the opposite direction is initiated. Thus, the sequence of connections indicated in Fig. 10B is obtained as the various contacts shown in Fig. 10 are actuated successively at successively increasing deflections of the feeler.

By means of a switch S (Fig. 10) order I can be converted by the operator into order II so that the carriage is moved in direction B while the rotary movement of the table which is normally initiated by the order I, does not occur. The cut-out switch S needs to be actuated only when the finger of the feeler is out of contact with the template. The switch S can be replaced by a further relay having an automatic holding contact actuated by a press button which is released as soon as the feeler passes into the next position.

Fig. 11 shows how a three-dimensional pattern is explored for the simultaneous machining of male and female counterparts. The three rotary tables 2, 3 and 4 are mounted on the carriage 1 of the milling machine which is arranged for displacement in the direction A-B. The pattern 5 is mounted on the rotary table 2 and will be felt by the feeler finger 6. While the rotary tables turn, the feeler and the two cutters are moved upwardly together in the direction C, so that the pattern is explored helically. The mechanism for producing the vertical movement can be coupled directly to the mechanism for rotating the tables or can be effected independently thereof at a constant speed. The feeler can be constructed so that its finger can also be deflected axially upwards or downwards, further contacts being provided for controlling through a reversible clutch the vertical movements of the support for the feeler and cutters.

Figs. 12-18 illustrate an electrical feeler control for such three-dimensional milling operations. A selector switch (Fig. 12) is provided for determining the appropriate method of exploration. This switch has six positions 1, 2, 3, 4, 5, 6, and the feeler is controlled in each of those positions in accordance with the schemes shown in Figs. 13A-18A.

In position 1 of the selector, the exploration is effected as shown in Fig. 13A. The feeler in that case provides for seven kinds of orders and connects the movements of the longitudinal carriage at different speeds to the control positions I-III. For order I, the cutter carriage advances very rapidly and that speed is decreased for the order II. For the order III, the longitudinal carriage advances at slow speed and stops completely for order IV. The rotary table rotates permanently and, in consequence, is not controlled by the feeler. For order V, the longitudinal movement of the cutter carriage changes direction: it starts moving, first of all slowly, and then for order VI, it advances normally and for order VII, it advances rapidly. That method of exploration is preferable for parts to be machined which have simple shapes, as indicated in Fig. 13. The machine works very rapidly when the round table turns permanently and, because of the adjustment of the speed, the movement of the longitudinal carriage adapts itself well to the shape of the part to be machined.

Fig. 19 shows diagrammatically the control system of a milling machine in which the exploration is as in Fig. 13A. The carriage 1 carrying the two rotary tables 3 and 4 is arranged for longitudinal movement on the base 60 by a screw 61. The pattern 5 is mounted on the table 4 for exploration by the feeler 18. The workpiece 8 is mounted on the rotary table 3 for being machined by the cutter 15. The screw 61 is driven through a magnetic clutch 10 and the tables through a magnetic clutch 9. The rotation of the tables can be arrested by a cut-out switch 62.

The feeler 18 is pivotally mounted at 63 and is arranged so that, as already described in connection with Fig. 10, the block 64 will be displaced upwards as a result of its deflection and contacts on the two sides of the block 64 will be actuated. With the spindle 65 of the feeler in the vertical position as shown, order I is initiated. The remaining orders II-VII are initiated as the deflection of the feeler increases, the relays R1-R4 being differently energised as described above

in connection with Fig. 10. Fig. 19A shows the different conditions of the relays and the movements controlled by the seven orders.

For adjustment of the longitudinal speed, a regulating cylinder 67 (Fig. 19) is provided, which is driven at constant speed. The regulating cylinder has brass or copper segments inlaid in an insulating cylinder, the segments being connected electrically to the contact ring 68 which is wiped by a brush 69 connected to the mains conductor P. Two further brushes 70 and 71 fixed to an insulating block 72 are arranged for displacement axially along the cylinder by means of a hand wheel 73. If the regulating cylinder is bridged, the clutch 10 turns the screw 61 at its full speed. If current is supplied to the clutch by the brush 70, the clutch turns at normal speed as described in the co-pending Applications hereinafter referred to. If the current is supplied by the brush 71, the clutch 10 turns at slow speed, the current supply being in the form of pulses of the same frequency but of shorter duration that when the brush 70 is operative.

For order I, the relays R1 and R3 are energised and the relays R2 and R4 are de-energised (see Fig. 19A). The relay R1 will receive current through the contacts 102 of the feeler as well as the contact 106 and the clutch 10 will be energised in the following circuit:

conductor P to terminal 121 over the closed working contact of relay R1—terminal 122—terminal 123—over the closed rest contact of relay R4 to terminal 124—terminal 125 of clutch 10—through the clutch winding to terminal 126 and back to mains conductor N.

For order II, the contact 102 is opened so that the relay R1 drops. Current is then supplied to the clutch 10 by the brush 70. The circuit is as follows:

conductor P—brush 69—contact ring 68—through the regulating cylinder to brush 70—terminal 127—closed rest contact of relay R2—terminal 128—terminal 129—closed rest contact of relay R1—terminal 130—terminals 123 and 124 of the closed rest contact of relay R4—terminals 125 and 126 of clutch 10—conductor N.

For order III, the feeler contact 103 will be closed so that the relay R2 will be energised. The clutch 10 will receive current through the brush 71. The circuit will be:

conductor P—brush 69—brush 71—contact 131 over the closed working contact of relay R3—contact 132—closed working contact of relay R2—contact 133—contact 130—terminals 123 and 124 of the closed rest contact of the relay R4—the terminals 125 and 126 of clutch 10—conductor N.

For order IV, the relay R3 drops and the clutch 10 is deprived of current.

For order V, the relay R4 is energised so that the current feed for the clutch 10 is directed over the terminal 134 and the direction of movement of the clutch 10 is changed. The clutch still turns at slow speed because it receives from the brush 71 only very short impulses.

For order VI, the terminal 134 of the clutch will receive current from the brush 70 so that the impulses are longer.

For order VII, the regulating cylinder is again short-circuited and the clutch turns faster.

For the method of exploration 2 determined by the selector of Fig. 12 and shown in Fig. 14A, the rotary table turns permanently but at a speed regulated by the feeler.

For order I, the longitudinal movement of the carriage is initiated; for order II, the table turns at high speed; for order III, the table turns more slowly; for order IV, the speed of rotation of the table is still more slow. When the feeler is deflected still further, the speed of rotation of the table will again increase. This manner of exploration is of advantage when the contour of the pattern has very pronounced variations of curvature as shown in Fig. 14.

The manner of exploration 3 (Fig. 15A) determined by the selector switch provides for five orders and for the manner of exploration 4 (Fig. 16A) seven orders.

The manner of exploration 5 (Fig. 17A) is particularly advantageous when the workpiece has rectilinear contours. The feeler controls the cross slide in seven different directions. For this reason the rotary table can turn at slow speed.

In the manner of exploration 6 (Fig. 18A), the vertical movement is also controlled so that the feeler can explore three-dimensionally. As shown in Fig. 18, the feeler spindle is drilled axially and the spindle S carrying the contact M at the foot slides in the axial bore. The spindle S is held in a central position by the springs S1, S2 so that a circuit is closed between the terminal H1 and the terminal H2. As a result, the magnetic clutch is supplied with current for the vertical support. When the spindle S is drawn outwards or pushed upwards axially by the finger of the feeler, the contact M will open and at the same time interrupt the vertical spindle movements. The construction and operation of the feeler are described in greater detail in the specifications of co-pending Applications Nos. 21839/52 or 23125/52 (Serial Nos. 759,697 and 759,701). The manner in which the contacts are actuated by the movements of the feeler is described in greater detail in co-pending Applications Nos. 22002/52 and 23125/52. (Serial Nos. 759,699 and 759,701.)

What we claim is:—

1. A copying machine tool in which rela-

tive movement between the tool and the workpiece is governed by electrical signals or orders produced as a result of the deflection of a feeler out of a normal position during exploration of a pattern by the feeler, the machine being provided with a table arranged for rectilinear displacement in opposite directions by electrical driving means controlled by the said orders and carrying at least one workpiece support arranged for movement relatively to the table by electrical driving means controlled by the said orders, and with a set of contacts which are actuated successively by the feeler as its deflection increases and which control relays arranged in the circuits of the driving means for the table and the support so that the support can be moved in at least five different manners.

2. A machine according to Claim 1 in which the contacts provide for seven different movements.

3. A machine according to Claim 2 in which a single one of the driven members is driven on receipt of certain orders while both the driven members are driven simultaneously on receipt of other orders.

4. A machine according to any preceding claim comprising means for regulating the speed of any one or both of the said movements.

5. A machine according to Claim 4 in which the speed regulation is effected by supplying the driving means with electrical pulses of adjustable duration.

6. A machine according to Claim 5 in which the speed regulation is effected through a device comprising a rotary cylinder having conducting parts separated from each other by non-conducting parts and which widen from one end to the other of the cylinder, and brushes wiping over the cylinder, the duration of the pulses being determined by the width of the conducting parts where they are wiped by the brushes.

7. A machine according to any preceding claim comprising a selector associated with the system of contacts whereby any one of a number of manners of exploration of the pattern can be selected.

8. A machine according to Claim 7 in which the contacts, the relays and the speed regulating means are interconnected by a number of groups of conductors each group being appropriate to a particular series of orders or manners of exploration and in which a selector switch is provided for selecting any desired series of orders.

9. A machine according to Claim 8 in which the groups of conductors are appropriate respectively to the initiation of: simultaneous rectilinear movement in either direction at different speeds and rotary movement at constant speed; simultaneous rectilinear movement in either direction at constant speed and rotary movement at different speeds; simultaneous rectilinear and rotary movements in each direction at constant speed; simultaneous rectilinear movement in either sense in two directions at an angle to each other; any one of the preceding movements and an additional vertical movement.

10. A machine according to any preceding claim in which the table carries a template support and at least one workpiece support, all the supports being arranged to be rotated in unison, on the receipt of certain orders, in one or the other sense.

11. A machine according to any one of Claims 1-7 in which the table carries a template support and at least one workpiece support, all the supports being driven rectilinearly in unison, on receipt of certain orders, in one or the other direction.

12. A machine according to any preceding claim comprising a pattern support and a workpiece support in the form of turntables driven in unison through a common electrically controlled clutch and a tool carrier which is adjustable relatively to the workpiece turntable to enable the tool to machine an internal contour complementary to the external contour of the pattern which is explored by the feeler.

13. A machine according to any preceding claim in which contacts are provided which are actuated by vertical displacements of the feeler to result in the vertical movements required by three-dimensional machining.

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Fig.6

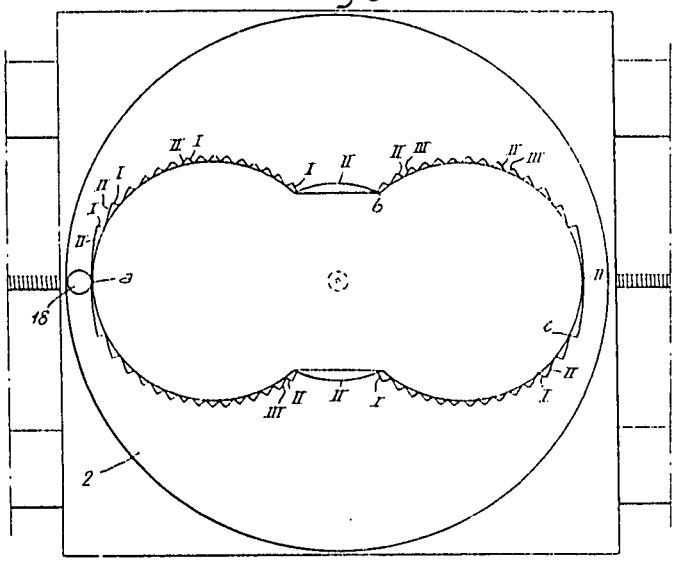

Fig.8

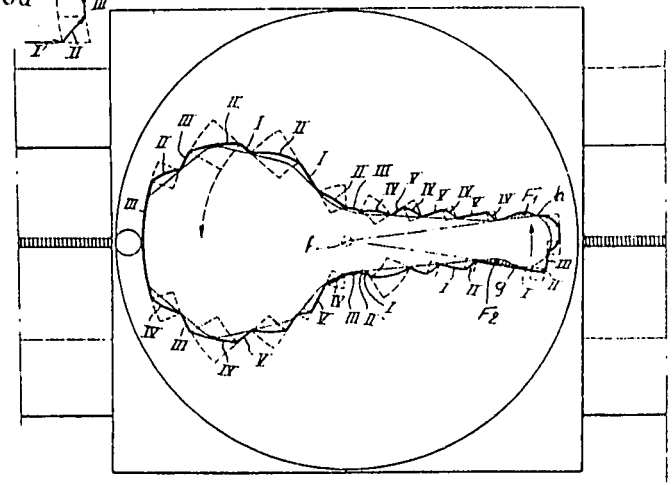

Fig 8a

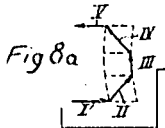

Fig.1

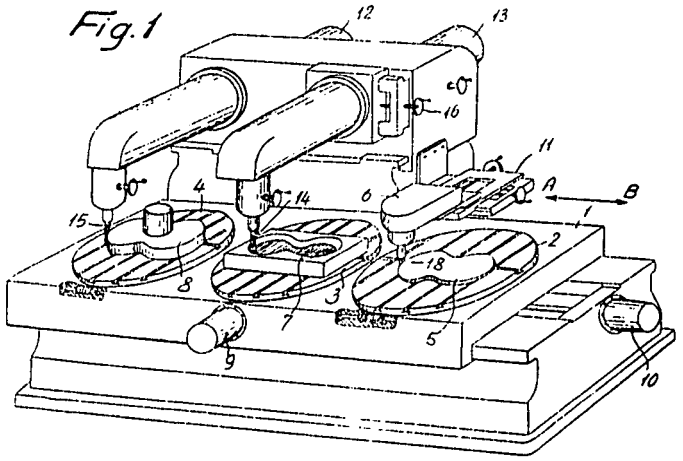

Fig.2

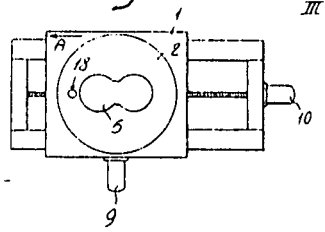

Fig.3

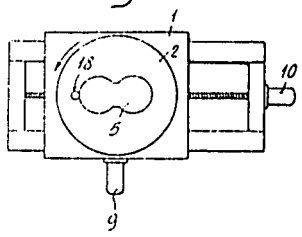

Fig.4

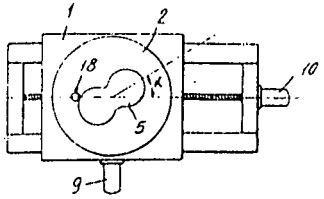

Fig.5

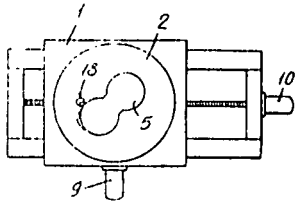

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Fig.7

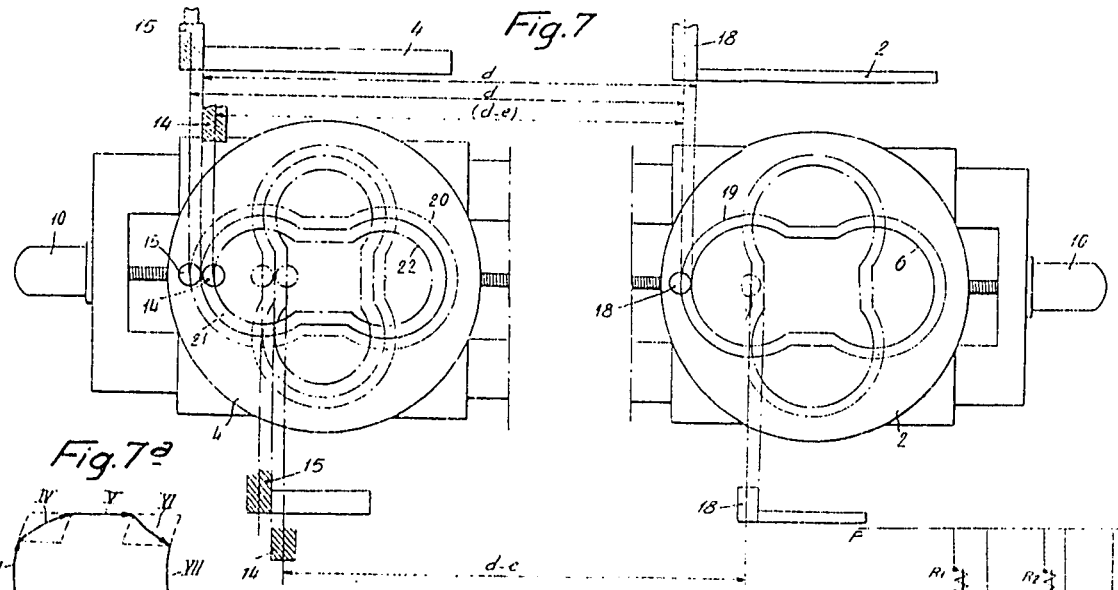


Fig.10a

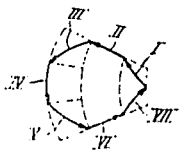


Fig.7a

Fig.10

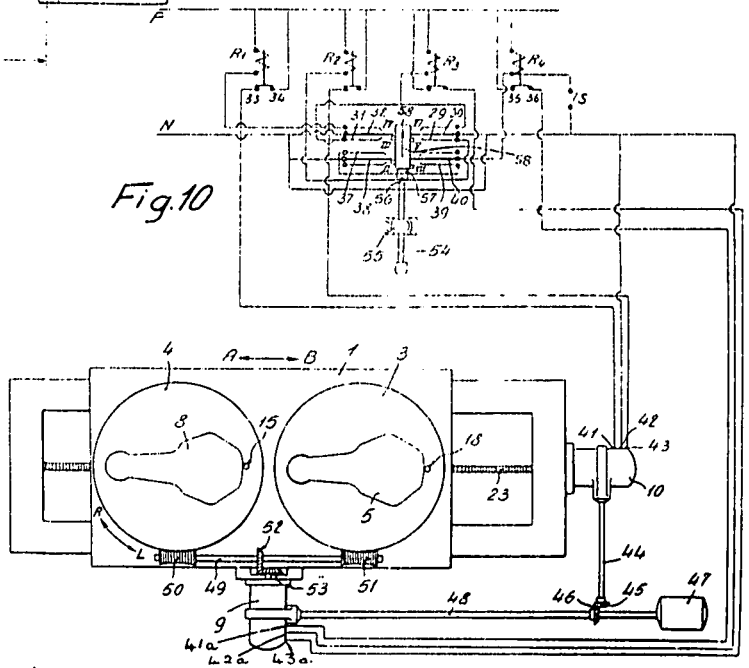


Fig.10b

Contact	R1	R2	R3	R4	Rotary switch	Switch movement
I	out	on	on	out	R	to B
II	out	on	on	on		to B
III	out	on	out	on	L	to B
IV	on	on	out	on	L	
V	on	out	out	on	L	to A
VI	on	out	on	on		to A
VII	on	out	on	out	R	to A

759,700 COMPLETE SPECIFICATION
4 SHEETS

Fig.9

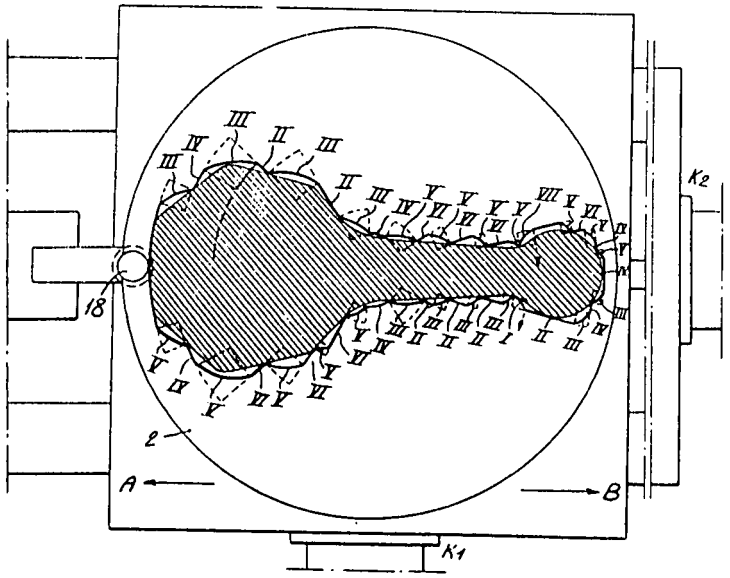


Fig.11

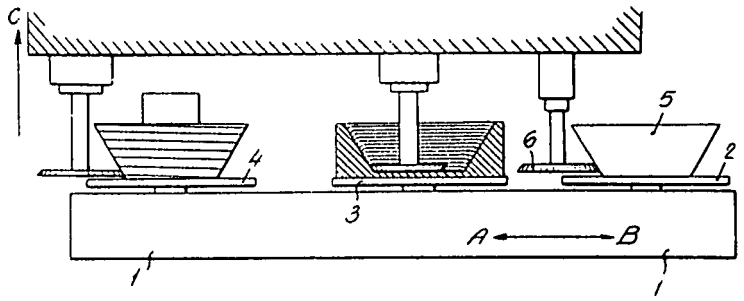
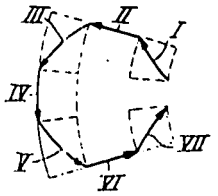


Fig.19a



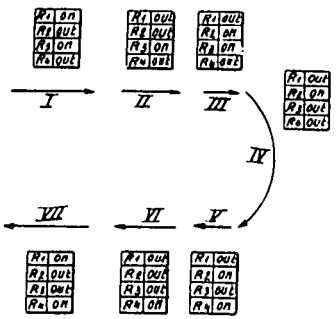
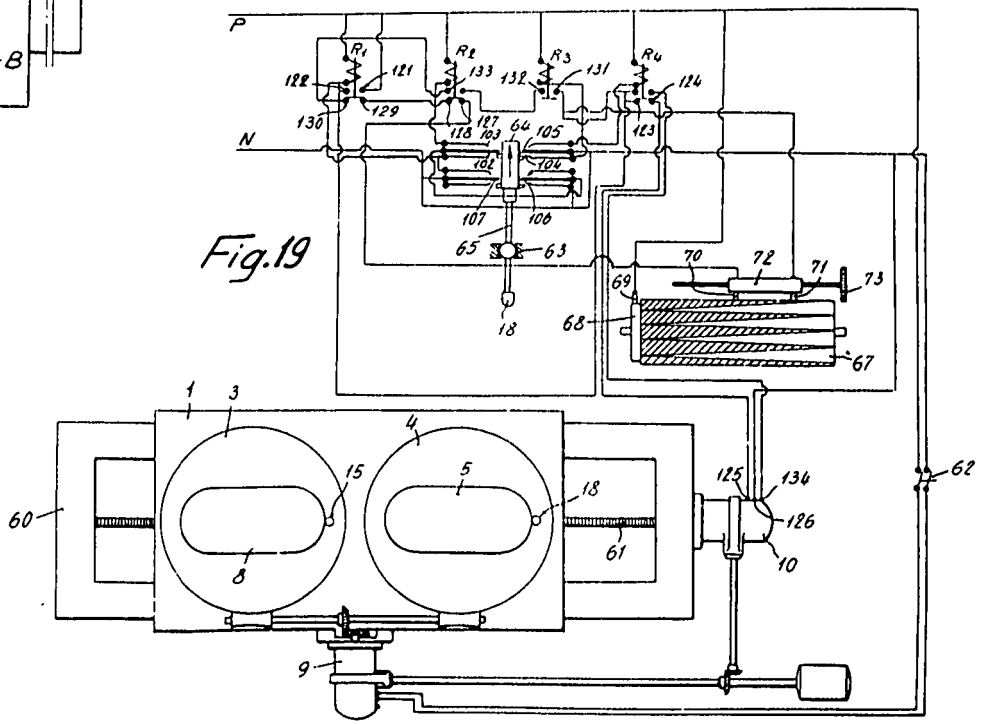


Fig.19



759,700 COMPLETE SPECIFICATION

4 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEET 4